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CROSS-BEDDING IN THE WHITE RIVER FORMATION OF NORTHWESTERN SOUTH DAKOTA

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Rocks of White River (Oligocene) age have been known for many years to constitute numerous isolated buttes and mesas in the northwest corner of South Dakota, but no detailed study of their character and structural relations had been made until 1911, when, during an examination of the lignite area of that country, the writer had occasion to study the relation of the younger rocks to those containing lignite beds.

Todd,[1] in 1895, recognized the White River formation in the Slim Buttes and called attention to the area in the following language:

> 3. Miocene beds, both White River and Loup Fork, with characteristic fossils, have been found overlying wide areas of the Laramie north of the Black Hills, covering quite deeply most of Harding County, with thin outliers over the north half of Butte County and south half of Ewing. In the Short Pine hills and Slim Buttes these deposits exhibit a depth of 200 to 400 feet with characteristic fossil features closely resembling those of the White River region.
>
> 4. An area of disturbance was found in the north half of Slim Buttes in northeast Harding County covering perhaps 20 to 25 square miles. This consists of sharp folds, including the Laramie and White River beds, with throws of perhaps 100 feet and dips of 25 degrees.

It is the purpose of this paper to show that the inclination of beds described above, as well as those exposed at several other localities in the Slim Buttes, is not a true dip due to a dynamic disturbance but is cross-bedding due to the peculiar manner of the accumulation of the White River formation.

White River beds, showing similar inclinations, are well exposed in at least three widely separated localities along the east side of the

[1] J. E. Todd, "Recent Geologic Work in South Dakota," *Am. Geologist*, XVI (1895), 202.

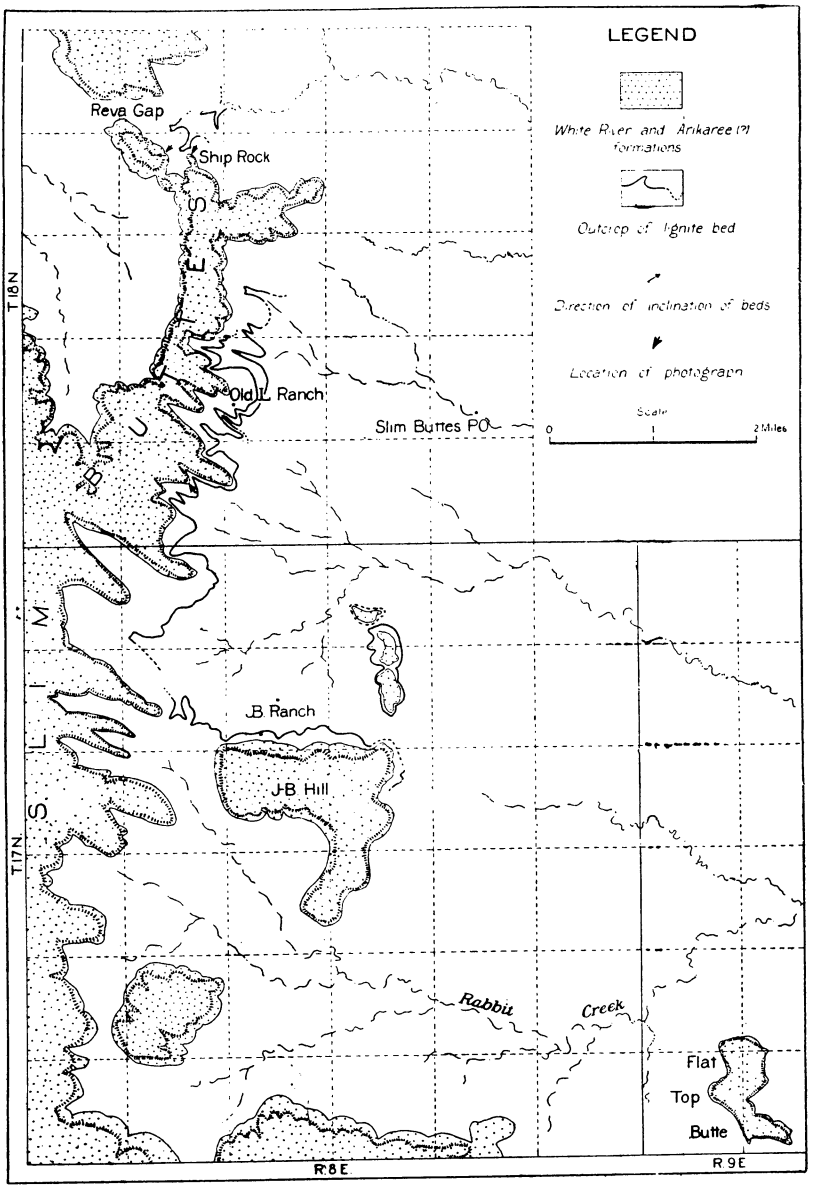

FIG. 1.—Map of part of the Slim Buttes, Harding County, South Dakota

Slim Buttes (Fig. 1): (1) in Reva Gap (Fig. 2), where the inclination is about 30° from the horizontal; (2) one-half mile south of the Old L Ranch (Fig. 4), where the inclination is about the same as in Reva Gap; (3) at the northwest angle of Flat Top Butte, where the inclination of beds is about 20°. In each case the inclined beds are overlain horizontally by a thick, characteristic sandstone, whose age is not definitely known but which has been doubtfully

FIG. 2.—Butte in Reva Gap. Height of cross-bedded portion about 75 feet

referred by Darton[1] to the Arikaree formation (Miocene). The strata beneath this sandstone include clay, marl, and sandstone, as shown in Fig. 3, in which fossils of Oligocene age are abundant. These, in turn, rest unconformably upon the lignite-bearing rocks of the region.

If the inclination of the beds in the White River formation is due to a disturbance of the strata, which occurred at the close of White River time, that inclination should also be evident in the underlying rocks of the immediate vicinity, but such is not the case, as is proven by the following facts:

[1] N. H. Darton, "Geology and Underground Waters of South Dakota," *Water Supply Paper, U.S. Geol. Survey*, No. 227 (1909), p. 21.

1. In the area between Old L Ranch and Flat Top Butte, about seven miles to the southeast, several flat-lying lignite beds are exposed, the outcrop of one (see Fig. 1) having been followed and prospected for a distance of several miles.

2. Between Reva Gap and Old L Ranch, numerous exposures show not only clay and sandstone beds of the White River formation but also the underlying lignite-bearing rocks to occupy a practically horizontal position. Ship Rock (Fig. 3), about 2,000 feet east of the point of which Fig. 1 is a photograph, exhibits White River beds

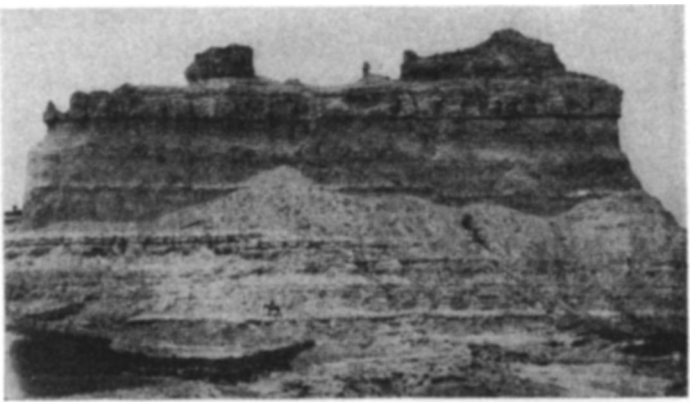

FIG. 3.—Ship Rock

in a horizontal position below the characteristic sandstone. (Photographs shown in Figs. 2 and 3 are taken looking in a southwest direction.) Hence the inclined beds cannot belong to a single anticlinal structure.

In the study of the lignite beds along the eastern margin of the Slim Buttes, still more convincing evidence was found to disprove the idea that the rocks of the region even in restricted areas were folded and faulted at the close of White River time. As is shown on the map (Fig. 1), a bed of lignite outcrops for several miles along the eastern side of the Slim Buttes in the vicinity of Old L Ranch. This bed occurs only a few feet below the White River formation and its outcrop is well exposed in sec. 32 near the point at which the photograph (Fig. 4) was taken. However,

at no point along its outcrop does the bed show a dip of more than 1°, the maximum inclination of lignite beds of the region, although it is known to outcrop in a canyon north as well as in one south of the high point in which the White River beds show apparent dips of about 30° to the southwest.

On all sides of the Slim Buttes there are large areas of slumped rocks where the attitude of the included beds seems to agree with the apparent dips exhibited in the White River beds which are known

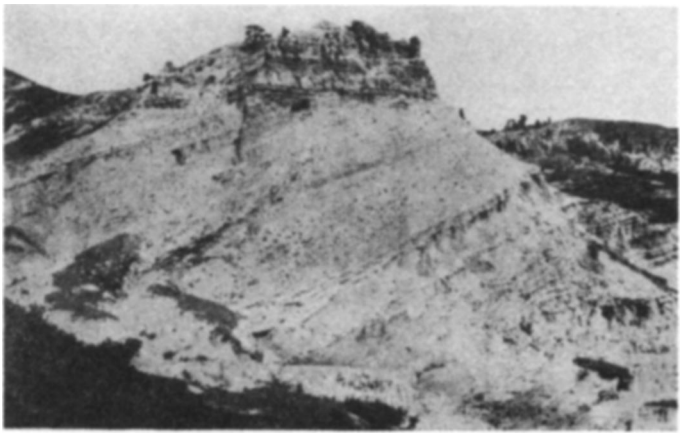

FIG. 4.—Rocky Point, one mile south of Old L Ranch. Height of cross-bedded portion about 100 feet.

to be in place, and it is probable that these slumped rocks have been seen by former geologists and used to substantiate the apparent structure described. One large area of the White River formation, which might easily be used in this respect, is to be found at the north end of the Slim Buttes where sandstone and clay about 125 feet in total thickness, one-half mile in length, and 500 feet in width, occur as a huge landslide now occupying the bottom of a narrow valley. The beds in this block dip 10 to 15° but there is little doubt that the whole mass has moved a considerable distance horizontally, as well as at least 100 feet vertically, from its former position. However, at each of the three localities above described, the cross-bedded White River formation is exposed in the face of

high buttes and is overlain horizontally by the massive Arikaree (?) sandstone which, like the underlying strata, shows no signs of having been disturbed by either landslide or folding.

That the cross-bedding so well exhibited in the Slim Buttes is not uncommon to the White River formation is indicated by the photograph (Fig. 5), taken on Shawnee Creek about nine miles west of Lost Spring, Wyoming. In that vicinity angles of inclination of from 1–22° were observed by the writer on heavy beds of

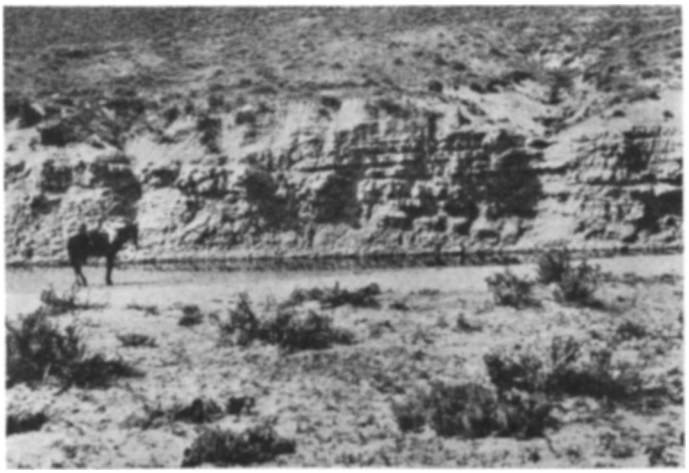

FIG. 5.—Cross-bedded sandstone in White River formation on Shawnee Creek, nine miles west of Lost Spring, Wyoming.

sandstones and conglomerate of White River age,[1] but no conclusive evidence was found suggesting deformation since the White River beds were laid down.

Until recently the rocks of the White River formation were supposed to have been deposited in a vast inland lake which covered portions of Colorado, Kansas, Wyoming, Nebraska, and the Dakotas. As the result of detailed studies, however, it is now believed by many geologists that a portion of the rocks at least were deposited along the flood-plains of shifting streams and perhaps in part by

[1] D. E. Winchester, "The Lost Spring Coal Field, Converse County, Wyo.," *Bull. U.S. Geol. Survey*, No. 471 (1912), p. 479.

wind action. The cross-bedding here described could hardly have been produced in deposits laid down in a large lake, and it requires a vivid imagination to assign it to wind action. Eolian deposits usually exhibit rather minute cross-lamination. On the other hand it is not unreasonable to assign this character of deposits to the action of shifting streams, and in that respect the author is inclined to agree with Hatcher[1] that at least part of the White River formation was accumulated as flood-plain deposits along shifting streams. Darton and others, in southern South Dakota, have been able to trace former river courses along which sandstone phases of the White River formation were deposited, but in the northwestern part of the state the formation occupies only small isolated buttes and it is impossible to trace the old drainage channels along which these remarkable examples of cross-bedding occur, so that definite data along this line cannot be obtained.

[1] J. B. Hatcher, "The Origin of the Oligocene and Miocene Deposits of the Great Plains," *Am. Philos. Soc., Proc.*, XLI (1902), 113–31.